DISPUTANDUM

The Supposed Use of the Lateral Line as an Organ of Hearing in Fish

In a recent review of the functioning and the significance of the lateral-line organs[1] I once again stressed the fact that electrophysiological and behavioural methods in the study of sensory functions must lead to results of different nature[2-4]. Electrophysiological studies provide evidence on the effectiveness of stimuli for the *receptor* organ proper, but they give no evidence as to whether these stimuli can also be used by the *animal* in its reactive behaviour. To decide about the use made of a receptor's capabilities, i.e. about its biological significance, only behavioural experiments are appropriate.

Consequently, the results from electrophysiological and behavioural experiments were discussed separately in my review. And when I concluded that in my opinion 'it does not seem appropriate to designate the lateral-line organs as "vibration receptors" or even as "a short-range auditory system" since the biologically adequate stimuli are neither essentially "vibratory" nor do they seem to include "sound" in the usual meaning of propagated, rhythmically repeated pressure waves' ([1], p. 59), this whole statement fell under the heading of 'behaviour experiments'. On the other hand, I never denied the responsiveness of the lateral lines to certain kinds of vibratory stimuli when studied by electrophysiological methods; I rather described these results under the appropriate heading ([1], p. 64/65).

The critical observations of several American authors with regard to my conclusions about the biological significance of the lateral-line system are off the mark because no account is taken of the difference mentioned above. Thus SUCKLING and SUCKLING[5], who found that the lateral-line receptors of fishes responded electrophysiologically to low-frequency water vibrations, felt obliged to 'rehabilitate' the concept of the system as a vibration perceptor 'despite the conclusions of DIJKGRAAF'. Likewise, VAN BERGEIJK[6] cites electrophysiological evidence that the lateral-line organ responds to near-field displacements of sound sources, and on that ground seems to feel authorized to correct my statements about the use made of this organ system, which are based on behavioural data. He even says: 'DIJKGRAAF's misconception appears to reside in the notion that a sound is necessarily *periodic*' ([6], p. 59). The reader may judge for himself from the quotation of the relevant sentence of my review (see above) whether it is justified to impute this notion to me. Parenthetically, I may confess that in my opinion still most sounds and – even if only by definition – all low-frequency vibrations *are* periodic[7]. Lastly, TAVOLGA and WODINSKY[8] write: 'DIJKGRAAF eliminated the lateral line as being a low-frequency sound detector', and again only electrophysiological evidence is cited in order to refute this view. Actually, I never 'eliminated' the lateral line as being a potential sound detector, but only attached due weight to the fact that up to the present most of the critical behaviour experiments yielded evidence against the use of lateral lines in sound detection, whereas unequivocal positive evidence is still lacking[9]. To quote again from my review: 'The lateral lines may participate in the detection of low-frequency sound sources at short range – this is still an open question – but they are apparently not engaged in the perception of propagated sonic or infrasonic sound waves' ([1], p. 94).

In order to avoid misunderstanding, I may add that the biologically adequate stimuli of the lateral-line organs, as determined by behavioural experiments, are water displacements acting locally on the fish body and particularly water displacements aroused by moving objects in the immediate neighbourhood of the object (*Stauungserscheinungen* or 'damming phenomena'). These displacements are much more akin to real water currents (to which the lateral lines are also most sensitive in behaviour experiments) than to sound (to which the lateral lines are apparently not sensitive in behaviour experiments). Therefore it seems to me only confusing to biologists if the lateral-line system is indicated as an acoustic receptor system[6], even though it might be possible to describe all water displacements in damming, technically correctly, in terms of a special (near-field) acoustic phenomenon. One might just as well indicate the semicircular canals of the labyrinth with their endolymph-displacement-sensitive cristae as an acoustic receptor system (see also[1], p. 59).

Finally, another critical observation of TAVOLGA and WODINSKY[8] is off the mark for the same reason that was mentioned earlier. The authors write: 'DIJKGRAAF also eliminated the functioning of the lateral line in the detection of locomotor currents. We fail to see the difference between water displacements produced by "moving obstacles" and those produced by the hydrodynamics of fish locomotion'. In reply to this, one can only say that, though the authors may fail to see this difference, the integrative centres of the fish brain evidently see it and differentiate quite well, as follows from the experimental facts presented in my review ([1], p. 80). Again a statement about the use made of the lateral-line system is mixed up with a statement about the physiological capabilities of the receptor organs proper[10]. In this way, apparent contradictions are created and unjustified criticism is brought about.

[1] S. DIJKGRAAF, Biol. Rev. *38*, 51 (1963).
[2] S. DIJKGRAAF, Z. vgl. Physiol. *27*, 587 (1940).
[3] S. DIJKGRAAF, Exper. *8*, 205 (1952).
[4] M. J. COHEN and S. DIJKGRAAF, in *The Physiology of Crustacea* (Academic Press, New York 1961), vol. 2.
[5] E. E. SUCKLING and J. A. SUCKLING, J. Acoust. Soc. Am., in press.
[6] W. A. VAN BERGEIJK, *Marine Bio-Acoustics* (Pergamon Press, New York 1964).
[7] A few erroneous statements in VAN BERGEIJK's article[6] may be briefly rectified: (a) The ability of fish to distinguish single tonal stimuli when two or three tones are presented simultaneously is no *terra incognita* but has been demonstrated by H. STETTER (Z. vgl. Physiol. *9*, 339 (1929)). (b) Neither VON FRISCH nor I have ever said that fish could swim up a sound gradient and find the source that way, i.e. directed. We rather stressed the opposite (K. VON FRISCH und S. DIJKGRAAF, Z. vgl. Physiol. *22*, 641 (1935)).
[8] W. N. TAVOLGA and J. WODINSKY, Bull. Am. Mus. Nat. Hist. *126*, 177 (1963).
[9] H. KLEEREKOPER and P. A. ROGGENKAMP (Can. J. Zool. *37*, 1 (1959)) claim to have obtained positive evidence, but this is not convincing because their experiment (with *one* animal) was not adequately controlled.
[10] TAVOLGA and WODINSKY[8] have also mixed up data from two of my articles on hearing in marine fish[11,12], one of which[12] is lacking in their reference list. One wonders why many parts of the fish body are considered in the discussion of the acoustical transparency of fishes except those which are presumably the most relevant in sound detection, namely the otoliths (see [11-13]).
[11] S. DIJKGRAAF, Physiol. comp. oecol. *2*, 81 (1950).
[12] S. DIJKGRAAF, Z. vgl. Physiol. *34*, 104 (1952).
[13] S. DIJKGRAAF, Proc. roy. Soc. *B 152*, 51 (1960).

Zusammenfassung. Die Untersuchung tierischer Sinnesorgane mit elektrophysiologischen Methoden kann die funktionellen Eigenschaften des Rezeptors als solchen klarlegen, sie berechtigt aber nicht zu Schlussfolgerungen über die funktionelle Bedeutung des betreffenden Sinnesorgans im Leben des Tieres. Zu solchen Schlussfolgerungen sind Verhaltensversuche erforderlich. Die Nichtbeachtung dieses unterschiedlichen Charakters der nach beiden Methoden erhaltenen Resultate führt zu scheinbaren Widersprüchen und zu unberechtigter Kritik, wovon einige rezente Beispiele angeführt werden.

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PRO EXPERIMENTIS

Application of Oscillographic Polarography in Photochemistry of some Deoxyribonucleic Acids

The influence of ultraviolet light (UV) and some photodynamically active organic dyes on the nucleic acids has been studied by numerous investigators[1-5]. Studies were carried out using different techniques but no electrochemical method has been used until now. The purpose of the following communication is to present results concerning the application of alternating current oscillographic polarography[6] in the investigation of the effects of UV-irradiation on the deoxyribonucleic acids (DNA's) isolated from two various sources.

The apparatus Polaroscope P 524 (Křižík, Prague) was used with a mercury dropping electrode, allowing us to follow the functions dE/dt against E. Samples of DNA's were analysed in the $0.5M$ ammonium formate medium ($pH = 7.0$) using a normal polarographic cells and the oscillograms were registered photographically[6].

All measurements were performed with original negatives magnified by optical projection. For this study the DNA's from calf thymus and *Escherichia coli* B were used in the dilute standard buffer ($0.015M$ sodium chloride $+ 0.0015M$ sodium citrate). Solutions of DNA's were irradiated 2–2.5 mm in depth on open dishes at a distance of 5 cm using a Philips TUV, 30 W, low pressure mercury lamp with an emission maximum at the wavelength of 2.537 Å. At the same time a part of the DNA solutions mentioned above was left as a control without UV-irradiation. Samples were denatured by heating at different temperatures for 10 min and quickly cooled in an ice bath[3]. The concentrations of DNA's were 50 μg/ml of the dilute standard buffer.

If highly polymerized DNA is subjected to alternating current oscillographic polarography in an ammonium formate medium, it produces a characteristic anodic indentation on the oscillogram (Figure 1, D) for which

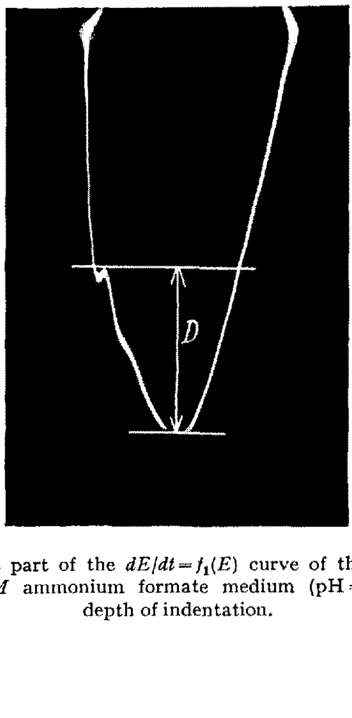

Fig. 1. Anodic part of the $dE/dt = f_1(E)$ curve of the calf thymus DNA in $0.5M$ ammonium formate medium ($pH = 7.0$). D = the depth of indentation.

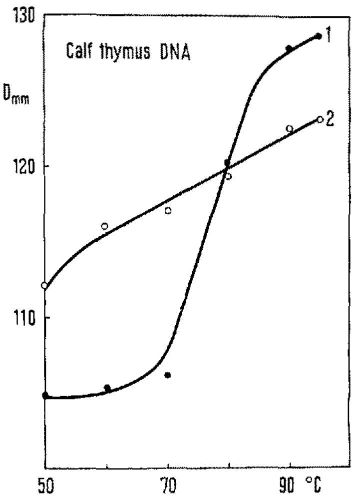

Fig. 2. Heat denaturation curves of the calf thymus DNA, derived from the oscillopolarographic measurements. Curve 1: DNA before the UV-irradiation. Curve 2: DNA after 60 min of UV-irradiation.

[1] E. Chargaff and J. N. Davidson, *The Nucleic Acids*, vol. III (New York 1960).
[2] J. Marmur, W. F. Anderson, L. Mathews, K. Berns, E. Gajewska, D. Lane, and P. Doty, J. cell. comp. Physiol. *58*, 33 (1961).
[3] L. Grossman, D. Stolar, and K. Herrington, J. Chim. phys. *58*, 1078 (1961).
[4] D. R. Cochran, A. Buzzell, and M. A. Lauffer, Biochim. biophys. Acta *55*, 755 (1962).
[5] M. I. Simon and H. Van Vunakis, J. mol. Biol. *4*, 488 (1962).
[6] J. Heyrovský and R. Kalvoda, *Oszillographische Polarographie mit Wechselstrom* (Akad. Verlag, Berlin 1960).